SUSY with long-lived staus at the LHC

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[arXiv:1206.5108 [hep-ph]]

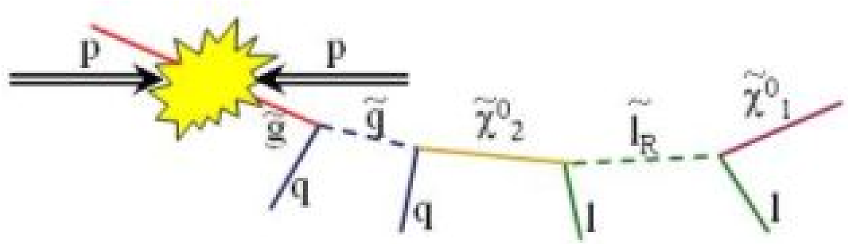
- Generic scenario of long-lived staus (LLST) with a significant mass gap with squarks/gluinos

  ⇒ Not identified from time of flight ($\beta \sim 1$) nor from $\mathrm{d}E/\mathrm{d}x$ (no anomalous ionization)

  A stau of $\mathcal{O}(100)$ GeV and a muon of same momentum loose similar (even less) energy [a function of $\beta\gamma$ with minimum at $\beta\gamma \approx 3$ reaching Fermi plateau for $\beta\gamma > 100$]

  ⇒ Detected as regular muons

- How do bounds on this SUSY compare to usual



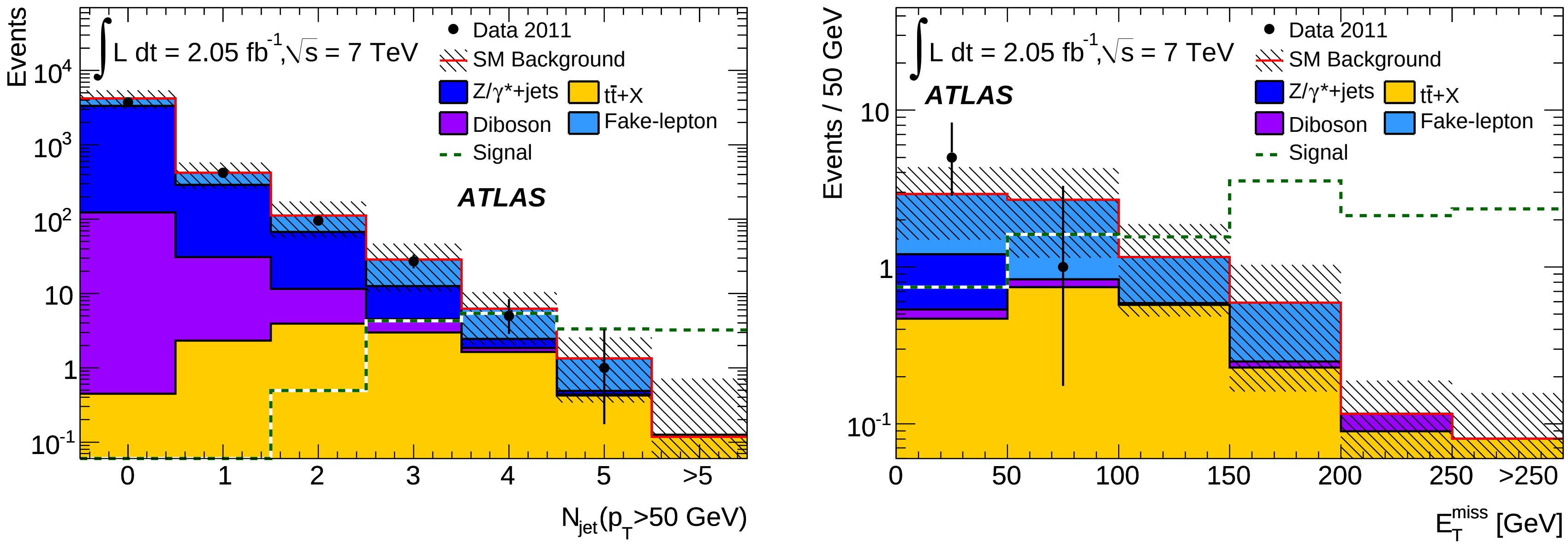
SS dileptons, jets and $\not\!\!E_T$ [arXiv:1203.5763 [hep-ex]] (2.05/fb @ 7 TeV) **ATLAS**

Two higher-p_T leptons SS ($\ell = e, \mu$), $N_{jet} > 3$ with $p_T > 50$ GeV, $\not\!\!E_T > 150$ GeV, isolation & η cuts

Background: $t\bar{t}Z$, $t\bar{t}W$, $t\bar{t}WW$, fake leptons, charge mis-ID $\Rightarrow$ $\sigma_{vis} = \sigma \times \epsilon \times A < 1.6$ fb $\epsilon = 55\%$

- ATLAS analysis Neutralino LSP of 150 (200) GeV
  - Gluino pair production $\tilde{g}[\to \bar{t}\ \tilde{t}_1(1.2\ \text{TeV})] \to \bar{t}\ t\ \tilde{\chi}^0_1$ $\Rightarrow$ $m_{\tilde{g}} > 770\ (750)$ GeV

$m_{\tilde{g}} = 650$ GeV:



SS dileptons, jets and $\not\!\!E_T$

(2.05/fb @ 7 TeV) **ATLAS**

- Our analysis LLST of 150 GeV (replaced by muon of same momentum) and Simplified Models

Differences: less $\not\!\!E_T$ ($\tilde\chi_1^0 \to \ell^\mp\tilde\ell^\pm$), two extra leptons (and more SS), strong μ-e asymmetry

– Gluino pair production

[B] $m_{\tilde\chi_1^0} \ll m_{\tilde\chi_1^+} \sim m_{\tilde\chi_2^0}$ $\tilde g \to \bar t\, t\, \tilde\chi_1^0 \to \bar t\, t\, \ell^\mp\tilde\ell^\pm$

[H] $m_{\tilde\chi_1^0} \sim m_{\tilde\chi_1^+} \sim m_{\tilde\chi_2^0}$ $\tilde g \to \bar t\, b\, \tilde\chi_1^+ \to \bar t\, b\, \nu_\ell\tilde\ell^+$ and changing (s)tops by (s)quarks

$\Rightarrow$

Model	gtB200	gtH200	gtH400	gqB200	gqB400	gqH200	gqH400
$m_{\tilde g}$ [GeV] >	890	880	980	605	830	875	1035

– Stop/squark pair production $\tilde t_1 \to t\, \tilde\chi_1^0 \to t\, \ell^\mp\tilde\ell^\pm$

$\tilde t_1 \to b\, \tilde\chi_1^+ \to b\, \nu_\ell\tilde\ell^+$ and changing (s)tops by (s)quarks

$\Rightarrow$

Model	qH200
$m_{\tilde q}$ [GeV] >	770

(tB200, tH200, qB200: unconstrained)

SS dileptons, jets and $\not{E}_T$

(2.05/fb @ 7 TeV) **ATLAS**

- Cut flow comparison

		$m_{\tilde{g}} = 650$ GeV		$m_{\tilde{t}_1} = 650$ GeV		$m_{\tilde{q}} = 650$ GeV	
Events	NLSP200	gtB200	gtH200	tB200	tH200	qB200	qH200
$\mathcal{L}\sigma\epsilon$	576	576	576	11	11	672	672
SS	17	209	199	4	3.4	258	275
$N_{\text{jet}} > 3$	12	185	159	2	1.7	52	48
$\not{E}_T > 150$ GeV	5	18	21	0.29	0.15	1.5	4.6
A [%]	1.2	3.2	3.6	2.6	1.4	0.2	0.7
$\sigma_{\text{vis}} = \sigma\epsilon A$ [fb]	3.4	9.1	10.4	**0.14**	**0.07**	**0.74**	2.22

$\Rightarrow$ LLST scenario has more SS dileptons and less $\not{E}_T$

Inclusive multilepton search [arXiv:1204.5341 [hep-ex]] (4.98/fb @ 7 TeV) CMS

3ℓ or 4ℓ, $\not{E}_{\rm T} \gtrsim 50$ GeV, $H_{\rm T} \gtrsim 200$ GeV, $S_{\rm T} \gtrsim 300, 600$ GeV, (no) Z, (no) OSSF, $\mathrm{N}(\tau_{\rm h}) = 0, 1, 2$

Background: VV, $t\bar{t}$, $t\bar{t}V$ Results presented as observed vs expected events

- About 25 000 observed events classified in regions (only 150 events are 4ℓ).
- In LLST models one expects high (low) $H_{\rm T}$ if mass gap between $\tilde{g}/\tilde{q}$ and $\tilde{\chi}$ is large (small)

⇒ Little room for New Physics:

- Example 1: gqH200 with $(m_{\tilde{g}},\ m_{\tilde{\chi}},\ m_{\tilde{\tau}}) = (650,\ 400,\ 150)$ GeV (high $H_{\rm T}$)

  where 2 500 $\tilde{g}\tilde{g} \Rightarrow 530\ (3\ell) + 74\ (4\ell)$

  [ruled out]

⇒ Anomalous 4ℓ events pointed out by CMS than can be cured:

- Example 2: qH tuned with $(m_{\tilde{q}},\ m_{\tilde{\chi}},\ m_{\tilde{\tau}}) = (1070,\ 1050,\ 200)$ GeV (low $H_{\rm T}$)

  where 92 $\tilde{q}\tilde{q} \Rightarrow 16\ (3\ell) + 8\ (4\ell)$

  [this and other models improve consistency with data but tend to predict a too low $S_{\rm T}$]

Inclusive multilepton search

(4.98/fb @ 7 TeV) **CMS**

Example 1: gqH200	$N(\tau_h) = 0$			$N(\tau_h) = 1$			$N(\tau_h) = 2$		
	obs	(SM)	**NP**	obs	(SM)	**NP**	obs	(SM)	**NP**
4 Lepton results									
$\not{E}_T > 50$, $H_T > 200$, no Z	0	(0.018±0.005)	**6.4**	0	(0.09±0.06)	**17**	0	(0.7±0.7)	**5.8**
$\not{E}_T > 50$, $H_T < 200$, no Z	1	(0.20±0.07)	**0.1**	3	(0.59±0.17)	**0.1**	1	(1.5±0.6)	**0.1**
$\not{E}_T < 50$, $H_T > 200$, no Z	0	(0.006±0.001)	**8.5**	0	(0.14±0.08)	**12**	0	(0.25±0.07)	**4.0**
$\not{E}_T < 50$, $H_T < 200$, no Z	1	(2.6±1.1)	**0.0**	5	(3.9±1.2)	**0.0**	17	(10.6±3.2)	**0.1**
3 Lepton results									
$\not{E}_T > 50$, $H_T > 200$, no-OSSF	2	(1.5±0.5)	**45**	33	(30.4±9.7)	**62**	15	(13.5±2.6)	**2.5**
$\not{E}_T > 50$, $H_T < 200$, no-OSSF	7	(6.6±2.3)	**0.0**	159	(143±37)	**0.4**	82	(106±16)	**0.0**
$\not{E}_T < 50$, $H_T > 200$, no-OSSF	1	(1.2±0.7)	**27**	16	(16.9±4.5)	**31**	18	(31.9±4.8)	**0.6**
$\not{E}_T < 50$, $H_T < 200$, no-OSSF	14	(11.7±3.6)	**0.1**	446	(356±55)	**0.0**	1006	(1026±171)	**0.0**
$\not{E}_T > 50$, $H_T > 200$, no Z	8	(5.0±1.3)	**116**	16	(31.7±9.6)	**62**		-	
$\not{E}_T > 50$, $H_T < 200$, no Z	30	(27.0±7.6)	**0.5**	114	(107±27)	**0.2**		-	
$\not{E}_T < 50$, $H_T > 200$, no Z	11	(4.5±1.5)	**72**	45	(51.9±6.2)	**30**		-	
$\not{E}_T < 50$, $H_T < 200$, no Z	123	(144±36)	**0.0**	3721	(2907±412)	**0.1**		-	

Inclusive multilepton search

(4.98/fb @ 7 TeV) **CMS**

Example 2: qH tuned	$N(\tau_h)=0$			$N(\tau_h)=1$			$N(\tau_h)=2$		
	obs	(SM)	**NP**	obs	(SM)	**NP**	obs	(SM)	**NP**
4 Lepton results									
$\not{E}_T > 50$, $H_T > 200$, no Z	0	(0.018±0.005)	**0.5**	0	(0.09±0.06)	**0.9**	0	(0.7±0.7)	**0.5**
$\not{E}_T > 50$, $H_T < 200$, no Z	1	(0.20±0.07)	**1.6**	3	(0.59±0.17)	**3.0**	1	(1.5±0.6)	**1.4**
$\not{E}_T < 50$, $H_T > 200$, no Z	0	(0.006±0.001)	**0.0**	0	(0.14±0.08)	**0.0**	0	(0.25±0.07)	**0.0**
$\not{E}_T < 50$, $H_T < 200$, no Z	1	(2.6±1.1)	**0.1**	5	(3.9±1.2)	**0.1**	17	(10.6±3.2)	**0.0**
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$\not{E}_T > 50$, $H_T < 200$, no-OSSF	7	(6.6±2.3)	**1.1**	159	(143±37)	**2.4**	82	(106±16)	**0.2**
$\not{E}_T < 50$, $H_T > 200$, no-OSSF	1	(1.2±0.7)	**0.0**	16	(16.9±4.5)	**0.0**	18	(31.9±4.8)	**0.0**
$\not{E}_T < 50$, $H_T < 200$, no-OSSF	14	(11.7±3.6)	**0.0**	446	(356±55)	**0.0**	1006	(1026±171)	**0.0**
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$\not{E}_T < 50$, $H_T < 200$, no Z	123	(144±36)	**0.1**	3721	(2907±412)	**0.0**		-	

Conclusions

- Focused on a SUSY scenario where staus are long-lived (NLSP with gravitino LSP) and fast (sizeable mass gap with parent colored particles)

- These LLSTs are indistinguishable from muons

- We have applied constraints from:
  - SS-dileptons, multijets and large $\not{E}_T$ (ATLAS)
  - multilepton searches (CMS)

- This SUSY scenario has less $\not{E}_T$, an excess of SS muon-like particles and a large μ-e asymmetry

- This SUSY is not hidden and seems to be as restricted as the usual one by ordinary searches